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# Empowerment Mechanisms and Empirical Evidence of Payment Technology in Capacity Expansion and Quality Improvement of Residents' Consumption

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**Abstract:** The time-varying difference-in-difference model is used to identify the impact of payment technology on residents' consumption, and the moderation effect analysis method is used to identify its mechanism. It is found that payment technology promotes consumption capacity expansion and quality improvement (CEQI) through three pathways of alleviating liquidity constraints, reducing transaction costs and weakening the payment of pain. The parallel and serial mechanisms of the three are further explored. The effect of payment technology on the CEQI of residents' consumption shows obvious heterogeneity due to differences in urban and rural household registration and financial literacy. Based on the empirical research results and the national conditions of China, targeted policy recommendations are proposed from the demand side, the supply side and the technological side.

**Key words:** payment technology; capacity expansion and quality improvement; residents' consumption; new quality productive force; time-varying difference-in-difference; moderating effect

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## 0 Introduction

The digital economy, as an important engine for economic development in the 21st century, has demonstrated significant influence and potential globally. Over the past few decades, with the rapid development of information technology and the widespread adoption of the internet, the digital economy has become a crucial force driving innovation, fostering economic growth, and improving people's livelihoods. At the same time, we cannot overlook the empowerment and transformation that the digital economy brings to traditional industries. Just as the development of textile technology and craftsmanship, the digital revolution is profoundly

altering the landscape of traditional sectors. In addition to changing the production methods of traditional industries and improving the efficiency of resource allocation, the digital economy has also created entirely new product and service models, forming new points of economic growth, making the digital economy itself an important form of new quality productive forces. Under the advocacy of accelerating the development of the digital economy, actively promoting the empowerment of the digital economy to expand consumption and improve quality and achieving effective qualitative improvement and reasonable quantitative growth in economic development, China is actively promoting the development of the digital economy. Meanwhile, consumption has played an increasingly crucial role among the three drivers and has become the primary force driving economic growth. The urgent task for China has been to further coordinate the promotion of the quality and speed of economic growth, leverage the positive role of consumption in promoting effective qualitative improvement and reasonable quantitative growth in the economy, and make new contributions to promoting high-quality economic development. Therefore, expanding domestic demand and stimulating consumption are essential steps to further promote high-quality economic growth in China.

Capacity expansion and quality improvement (CEQI) of residents' consumption refers to further expanding the scope of new consumption and improving the quality of new consumption. The term empowerment refers to endowing a certain subject with certain abilities and strengths. Some scholars believe that the development of payment technology has driven the development of e-commerce and lending platforms, profoundly changing people's lifestyles, improving residents' payment efficiency, promoting consumption CEQI, driving economic growth, and making the "cake" bigger<sup>[1]</sup>. In China, what is the relationship between payment technology and resident consumption? What

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kind of empowerment mechanism exists between payment technology and resident consumption? Existing literature mainly focuses on studying the mechanism of consumption empowerment from the perspective of alleviating liquidity constraints of either physical credit cards<sup>[2]</sup> or virtual third-party payment platforms<sup>[3]</sup>, lacking comprehensive analysis of the overall impact of payment technology on the structure and quantity of residents' consumption, and failing to delve into the interrelationships between various pathways, resulting in an incomplete characterization of the relationship between payment technology and residents' consumption. In addition, the selected intermediary effect models have been challenged in recent years, rendering the mechanism verification analysis results unconvincing. This paper combines physical and virtual payment technologies and their derivative products for research, analyzes their dual impacts on consumer consumption quantity and structure, and draws on the models of regulatory effect testing by Wen et al.<sup>[4]</sup> and Jiang<sup>[5]</sup>. This study aims to explore the implementation paths and path correlations of payment technology in promoting the CEQI of residents' consumption. It seeks to investigate how payment technology as a whole can promote the CEQI of residents' consumption in China, driving high-quality economic development through the effects of overall enhancement, quality upgrading, structural optimization, and internal linkage.

## 1 Theoretical Expression and Research Hypotheses

### 1.1 Review of literature

The development of the Chinese economy has entered a new normal. The traditional model of economic growth driven by investment and exports is clearly inadequate, while at the same time, the contribution of residents' consumption to the Chinese economy continues to increase. Against the backdrop of the widespread development of Internet technology in the 1990s and the vigorous growth of the e-commerce industry, the use of payment technology for consumption has emerged and continues to spread. Domestically and internationally, the mechanism for promoting the CEQI of residents' consumption through payment technology is analyzed from three aspects: alleviating liquidity constraints, reducing transaction costs, and weakening payment pain<sup>[6]</sup>.

In the process of China's transition from a saving culture<sup>[7-8]</sup> to a consumption culture, the significant role played by credit cards cannot be ignored. Academia mostly studies the relationship between credit cards and residents' consumption quantity from a micro perspective. It is believed that the use of credit cards significantly promotes residents' consumption by providing short-term liquidity to residents. The scale of

revolving credit card debt shows a significant inverted U-shaped relationship with residents' consumption expenditure. Revolving credit card debt leads to additional consumption by cardholders through a causal mechanism consisting of stabilization effects, expansion effects and floating effects<sup>[9]</sup>. Based on the credit card balance compensation mechanism, it was found that the credit card balance compensation system actually provides consumers with low-interest unsecured short-term loans, thereby significantly increasing consumers' total consumption<sup>[10]</sup>. Using a combination of propensity score matching and fixed effects, it was empirically found that holding credit cards significantly promotes residents' consumption by alleviating liquidity constraints<sup>[10]</sup>. However, at the same time, increasing consumer credit may increase the likelihood of consumers adopting non-full repayment methods, thereby increasing the risk for financial institutions<sup>[11]</sup>. In addition, according to Maslow's hierarchy of needs theory, the use of credit cards can also promote the transformation and upgrading of residents' consumption. Wang et al.<sup>[12]</sup> found that credit card payments are significantly negatively correlated with the proportion of survival-type consumption expenditure and significantly positively correlated with the proportion of enjoyment-type and development-type consumption expenditure, leading to the conclusion that credit card payments can achieve an upgrade in consumption structure through credit expansion mechanisms.

The enormous consumer demand and rapid development of science and technology in China have also promoted the emergence and development of other payment technologies besides credit cards, such as mobile payments and Internet payments, giving rise to third-party payment products represented by Alipay, WeChat Pay and Baidu Wallet. As a new type of online payment mode, they play an increasingly significant role in residents' consumption and have become an important channel for consummating consumption transactions. Firstly, payment technology can directly promote the increase in residents' consumption by providing credit to alleviate residents' liquidity constraints, and it has heterogeneous effects on consumption in urban and rural households. It can significantly promote the increase in total consumption and enjoyment-type consumption in urban households, while the increase in total consumption in rural households is not significant and focuses more on survival-type consumption<sup>[13]</sup>. Secondly, according to the analysis of theories such as consumer equilibrium, payment technology can stimulate residents' consumption by reducing time costs, search costs and payment costs. Pei et al.<sup>[14]</sup> found that there is a long-term equilibrium relationship between mobile payments and residents' consumption, indicating that mobile payments have a certain stimulating effect on residents' consumption and can bring residents' consumption back to equilibrium.

Mobile payments are not only substitutes for cash and bank card payment methods but also effectively promote residents' consumption, ultimately achieving the effect of promoting the sustained and healthy development of the national economy. However, the subsequent weak supervision of payment platforms, lack of protection, leakage of user privacy and other behaviors bring negative value perception to consumers, reducing their willingness to use them, which to some extent inhibit consumer demand<sup>[15]</sup>. Finally, payment technology can promote the CEQI of residents' consumption by weakening the sense of payment. Electronic payment methods convert money into digital spending, which reduces the sense of pain compared to a large amount of cash, and even makes the payment less painful or painless. In addition, methods such as small-value exemptions and fingerprint payment passwords further accelerate the payment speed and increase the probability of impulsive consumption by consumers. Through empirical analysis from the perspective of the "dual-channel mental accounts theory", it was found that mobile payments can affect residents' consumption by reducing the sense of payment, with the greatest impact on food expenditure and the smallest impact on entertainment expenditure<sup>[16]</sup>.

## 1.2 Theoretical basis and research hypotheses

According to the theory of liquidity constraints, when individuals have temporarily negative income and cannot borrow based on future expected income, and their own wealth accumulation cannot meet their necessary consumption, they can be considered as being subject to liquidity constraints. This leads to some consumers consuming based on current income, resulting in excessive sensitivity of consumption changes to income, and even refusal to consume. The development of payment technology improves the credit function of payment technology, thereby alleviating liquidity constraints and promoting the expansion and upgrading of residents' consumption capacity. For example, some payment platforms, including Ant Credit Pay and JD White Bar, provide consumers applying for loans with a period of interest-free repayment. As long as the loan is repaid within the interest-free period, no interest needs to be paid, which means that the better the consumer's credit limit, the more interest costs can be saved. At the same time, consumers can also choose installment payment methods, which are both safe and convenient. Compared with traditional bank credit, payment technology has more flexibility, thus having a greater impact on residents' consumption. However, in recent years, more and more third-party lending platforms have been exposed to dishonesty, privacy breaches, and other issues, leading to more cautious observation of these platforms by residents, which has inhibited the consumer demand and the optimization of consumption structure to some extent. This study refers to the process of payment technology promoting the expansion and upgrading of

residents' consumption capacity by alleviating liquidity constraints as the liquidity constraint relief effect.

Coase's transaction cost theory<sup>[17]</sup> points out that transaction cost refers to the cost incurred by individuals in a specific social environment to reach a transaction, which is the cost of relationships between people. Regardless of the payment method used, transaction costs exist in the process of completing transactions whenever there is a transaction, but there are differences in the level of transaction costs among different transaction methods. Rational consumers will choose the optimal payment method to reduce their transaction costs, complete the purchase behavior, and thereby maximize utility. Compared to traditional payment methods, payment technology can reduce transaction costs and maximize consumer utility in the following three aspects.

### 1) Reducing time costs

When using traditional payment methods (such as cash), people need to spend time selecting items in the store and waiting in line to pay and receive change. In contrast, using payment technologies such as scanning payment greatly improves efficiency. At the same time, the development of the Internet and e-commerce platforms (such as Taobao, JD and Pinduoduo) allows consumers to shop easily at home without leaving, not only saving travel time but also providing consumers with a wide range of goods from home and abroad, covering affordable goods or high-end luxury goods. These platforms also reduce consumer search time by tracking consumer preferences and providing homepage recommendations, increasing consumer awareness of spending.

### 2) Reducing payment costs

In recent years, with the continuous development and growth of the Internet, major e-commerce platforms have also flourished, and various activities such as Taobao's Double Eleven, Double Twelve, JD 618 Carnival, New Year's Goods Festival and Goddess Festival have emerged endlessly under the dominance of major e-commerce platforms or merchants. These platforms or merchants take advantage of the holiday opportunities to provide benefits to consumers in the form of discounts, coupons and tasks to share red envelopes, thereby promoting the CEQI of residents' consumption by reducing payment costs.

### 3) Reducing opportunity costs

In the textile industry, digital design software and intelligent production equipment enable firms to precisely control quality, customize production, and meet personalized consumer demands. This transformation reduces costs, shortens production cycles, and enhances responsiveness to market demands, driving consumption growth. The theory of money demand includes transaction, speculative, and precautionary needs. Traditionally, people kept cash for emergencies. However, with payment technologies like Yu'e bao and

WeChat, consumers can store money in electronic accounts that are easily accessible and offer returns, reducing opportunity costs.

Thaler's theory of mental accounting<sup>[18]</sup> emphasizes that people psychologically differentiate wealth from different sources into different mental accounts, making wealth between accounts difficult to transfer and exhibiting irrational behavior, which contradicts the assumption of rational individuals in economics. For example, using the change in WeChat payment may come from red envelopes or financial returns, giving consumers an impression of easy access, thereby increasing consumer desire. Building upon the mental accounting theory, Prelec et al.<sup>[19]</sup> further proposed the double-entry mental accounting theory to explain consumers' prepayment preferences. This theory suggests that consumers have two channels in their brains during consumption decisions: one records the satisfaction after payment (positive utility), and the other records the pain of payment (negative utility). These two feelings coexist in the shopping experience, influencing consumer decisions. If the sum of the two is positive, the consumption experience is satisfactory; if negative, it is not. The closeness between consumption and payment behaviors can be further represented by the term linkage. The longer the time interval between purchase and payment, the weaker the pain of payment consumers feel. Traditional payment methods such as cash have a close linkage between consumption and payment, leading to a strong sense of payment pain and generating negative utility. In contrast, payment methods of payment technologies have the characteristic of low payment transparency, which weakens the linkage between consumption and payment, thereby reducing the pain of payment and bringing more positive utility to consumers, thus promoting the expansion and improvement of consumer consumption. Additionally, Soman<sup>[20]</sup> proposed that among cash, debit cards, credit cards and other electronic payment methods, the degree of pain from fund outflows was continuously decreasing. In this study, the process of payment technology promoting the expansion and improvement of consumer consumption by weakening the pain of payment is referred to as the payment pain reduction effect.

Based on the above analysis, the mechanism and pathway of payment technology promoting the CEQI of residents' consumption are summarized in Fig. 1, and one main effect benchmark research hypothesis and three transmission mechanism hypotheses are proposed as follows.

**Hypotheses 1:** Payment technology promotes residents' consumption, achieving expansion and improvement in quality.

**Hypotheses 2:** In the process of payment technology promoting the expansion and improvement in the quality of residents' consumption, the mechanism for alleviating

liquidity constraints plays a positive regulatory role.

**Hypotheses 3:** In the process of payment technology promoting the expansion and improvement in the quality of residents' consumption, the mechanism for reducing transaction costs plays a positive regulatory role.

**Hypotheses 4:** In the process of payment technology promoting the expansion and improvement in the quality of residents' consumption, the mechanism for weakening payment pain plays a positive regulatory role.

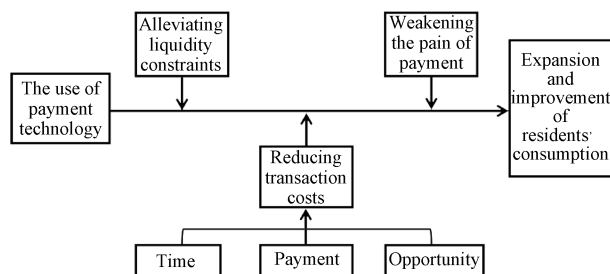


Fig. 1 Mechanism and pathway of payment technology promoting the CEQI of residents' consumption in this study

## 2 Data and Mathematical Modelling

### 2.1 Data sources

The main data in this paper is derived from the China household finance survey (CHFS) conducted by the Southwestern University of Finance and Economics, using publicly available data for the years 2013, 2015, 2017 and 2019<sup>[21]</sup>. Due to the need for a time-varying difference-in-differences model approach, this paper further selects households successfully tracked in four consecutive years of surveys. Additionally, due to potential response biases among questionnaire respondents, this paper further excludes invalid data for empirical analysis. Furthermore, this paper supplements necessary missing data using the data from Ref. [22].

### 2.2 Models

#### 2.2.1 Baseline models

To examine the impact of payment technology on the CEQI of residents' consumption, this study employs a two-way fixed-effects time-varying difference-in-differences model for estimation, with individual and year fixed effects, attempting to control for other factors affecting the CEQI of residents' consumption. The baseline model is set as follows:

$$y_{1,i,t} = \alpha_0 + \alpha_1 D_{i,t} + \alpha_2 C_{i,t} + U_i + Z_t + \varepsilon_{i,t}, \quad (1)$$

$$y_{2,i,t} = \alpha_0 + \alpha_1 D_{i,t} + \alpha_2 C_{i,t} + U_i + Z_t + \varepsilon_{i,t}, \quad (2)$$

where  $i$  represents households;  $t$  represents time;  $y_{1,i,t}$  denotes the logarithm of the total consumption expenditure of household  $i$  in year  $t$ ;  $y_{2,i,t}$  represents consumption structure of household  $i$  in year  $t$ ;  $D_{i,t}$  is a dummy variable for the policy effect brought by the use of payment technology;  $C_{i,t}$  denotes the control variable set;  $U_i$  represents individual fixed effects;  $Z_t$  represents

time-fixed effects;  $\varepsilon_{i,t}$  denotes the random error term;  $a_0$  is the intercept term, which represents the spontaneous consumption without other factors.;  $\alpha_1$  represents the parameter to be estimated;  $a_2$  represents the degree of influence of the control variable on the explained variable.

### 2.2.2 Mechanism testing models

This paper explores the mechanism of how payment technology facilitates the EIRC quantitatively. Referring to the moderation effect model and testing procedures in Refs. [4] and [5], the following econometric model is established:

$$y_{1,i,t} = \beta_0 + \beta_1 D_{i,t} + \beta_2 C_{i,t} + \beta_3 M_{c,i,t} + \beta_4 M_{c,i,t} D_{c,i,t} + U_i + Z_t + \varepsilon_{i,t} \quad (3)$$

$$y_{2,i,t} = \beta_0 + \beta_1 D_{i,t} + \beta_2 C_{i,t} + \beta_3 M_{c,i,t} + \beta_4 M_{c,i,t} D_{c,i,t} + U_i + Z_t + \varepsilon_{i,t} \quad (4)$$

where  $M_{i,t}$  is the moderator, representing the variable that may moderate the process of payment technology influencing the CEQI of residents' consumption;  $D_{c,i,t}$  represents the decentralized  $D_{i,t}$ ;  $M_{c,i,t}$  represents the decentralized  $M_{i,t}$ ;  $\beta_0$  is the intercept term, which represents the spontaneous consumption without other factors;  $\beta_1$  represents the parameter to be estimated;  $\beta_2$  represents the degree of influence of the control variable on the explained variable;  $\beta_3$  represents the degree of influence of the moderating variable on the explained variable;  $\beta_4$  is the coefficient of the interaction term between the moderator and independent variable, representing the size and direction of the moderating effect.

Based on the above explanation, if the coefficient  $\beta_4$  is significant and has the same sign as  $\beta_1$ , it can be considered that the moderator variable significantly enhances the effect of payment technology on the CEQI of residents' consumption; if the coefficient  $\beta_4$  is significant and has the opposite sign to  $\beta_1$ , it can be considered that the moderator variable significantly weakens the effect of payment technology on the CEQI of residents' consumption. To alleviate the issue of high collinearity between the interaction term and the independent variable and moderator variable, the core explanatory variable and the moderator variable are decentered.

## 2.3 Variables

### 2.3.1 Dependent variables

The dependent variables in this study are indicators of measuring the CEQI of residents' consumption. Drawing on Maslow's hierarchy of needs theory and other similar literature, this study selects two indicators: total residents' consumption and the proportion of development-oriented consumption to total consumption in the year. If the proportion of total residents' consumption and development-oriented consumption to total consumption significantly increases with the use of

payment technology, it can be considered that the policy significantly promotes the CEQI of residents' consumption. To overcome linear relationships, the natural logarithms of the two indicators are taken and named  $y_1$  and  $y_2$ , respectively.

### 2.3.2 Explanatory variables

The core explanatory variable in this paper is the policy effect brought by payment technology, represented by the dummy variable PayTech \* post ( $D$ ).  $D = 1$  represents the experimental group, namely households using payment technology; otherwise,  $D = 0$  represents the control group, namely households not using payment technology. The annual post when using payment technology is coded as 1, while other years are coded as 0. The regression results mainly refer to the positive or negative significance of PayTech \* post (referred to as  $D$  in subsequent empirical analyses). Due to differences in questionnaire settings in different years of the CHFS, different questions are used to determine whether households use payment technology.

In this study, the definition of payment technology adopts the concept specified in the payment technology guidance published by the People's Bank of China: payment technology refers to the behavior of units or individuals directly or authorizing others to issue payment instructions through electronic terminals to achieve currency payment and fund transfer. Payment technology is classified into different service types according to the method of initiating payment instructions: online payment, telephone payment, mobile payment, point-of-sale terminal transactions, automatic teller machine transactions and other electronic payments. Based on this definition, this study determines whether households use payment technology based on questionnaire responses. Due to differences in questionnaire settings in different years of the CHFS, different questions are used as indicators to determine whether households use payment technology.

### 2.3.3 Control variables

Through the collection and analysis of literature with similar themes, drawing on theories such as the life cycle proposed by Modigliani (1954), this paper focuses on controlling the influence of relevant factors at the household level. Specifically, it includes age  $A$ , age squared  $B$ , gender  $S$ , family size  $F$ , total assets  $T$ , and total income  $I$ .

### 2.3.4 Moderator variables

Based on the previous analysis of the mechanism, payment technology will affect the CEQI of residents' consumption quality through three pathways: alleviating liquidity constraints, reducing transaction costs and weakening payment pain. According to the requirements of empirical analysis, credit loan  $Q$  and financing constraint index  $X$  are selected as measurement indicators for analysis in the alleviating liquidity constraints section; in the reducing payment costs section, the regional level of electronic information development  $V$  is

chosen as the measurement indicator for analysis; and in the aspect of weakening the pain of payment, the consumer price index  $P$  is adopted as the measurement indicator for analysis.

**2.4 Descriptive statistics of variables**

The descriptive statistics of the variables are presented in Table 1. Regarding individual

characteristics, the average age of the respondents is approximately 55.273 years old, with the youngest respondent being 16 years old and the oldest being 96 years old. Male household heads outnumber female household heads. The average household size is 3.874. The mean total assets of the households are 793 529 CNY, and the mean total annual income is 63 106 CNY.

**Table 1** Descriptive statistics

Variable	Meaning	Number	Mean	Standard deviation	Minimum	Maximum
$y_1$	Natural logarithm of total consumption	24 952	10.571	0.963	0	18.949
$y_2$	Natural logarithm of consumption structure	24 952	-0.844	0.635	-9.655	0
$D$	Whether the electronic payment is used (if it is used, $D=1$ ; else, $D=0$ )	24 952	0.256	0.436	0	1
$A$	Head of household age	24 952	55.273	13.399	16	96
$B$	Square of the head of household age	24 952	3 234.569	1 468.722	256	9 216
$S$	Gender of the head of the household (if the head is male, $S=1$ ; else, $S=0$ )	24 952	0.545	0.498	0	1
$F$	Family size	24 952	3.874	1.824	0	24
$T$	Total family assets/CNY	24 952	793 529	1 592 731	0	30 000 000
$I$	Total family annual income/CNY	24 952	63 106	153 025	0	7 863 131
$L$	Amount of household credit loans/CNY	24 952	190.716	143.470	0.070	525.245
$X$	Analogy to the corporate financing constraint index, measuring the degree of household financing constraint ( $SA\ index = -0.737 \times family\ size + 0.043 \times family\ size \times family\ size - 0.04 \times age$ )	24 952	-4.278	0.715	-6.864	0
$V$	Regional digitalization level	24 952	241.110	47.587	106.830	340.008
$P$	Consumer price index	24 952	102.125	0.638	101.400	102.900

Note; SA index is an index usually used to measure the degree of corporate financing constraints, and here it is used to measure the degree of household financing constraints.

**3 Baseline Model Results and Mechanism Identification**

This section begins with conducting parallel trend tests to determine whether the samples before and after the adoption of payment technology have the comparability prerequisite for using time-varying difference-in-difference. Subsequently, the relationship between payment technology and residential consumption is examined through a baseline regression using the double-fixed time-varying double-differences model. Finally, the moderation effect test model is applied to identify the mechanism by which payment technology facilitates the expansion and improvement of residential consumption.

**3.1 Analysis of parallel trend tests**

Samples using the time-varying difference-in-

differences model must meet the premise of comparability. Therefore, the parallel trend test should be conducted first to determine whether the samples before and after the introduction of payment technology have the comparability required for using the time-varying difference-in-differences model. To assess the impact of the policy of payment technology, the samples are divided into experimental and control groups. The testing method for evaluating the policy effect using the time-varying difference-in-differences model is based on a counterfactual framework to assess changes in the dependent variables under the circumstances of being affected and not being affected by the policy. Therefore, based on relevant scholars' research, a parallel trend test model based on the event study method is established. The specific model settings can be seen in Eqs. (5) and (6).

$$y_{1,i,t} = \beta_0 + \sum_{\tau=-m}^n \beta_{\tau} D_{i,t-\tau} + \beta_2 C_{i,t} + U_i + Z_t + \varepsilon_{i,t}, \quad (5)$$

$$y_{2,i,t} = \beta_0 + \sum_{\tau=-m}^n \beta_{\tau} D_{i,t-\tau} + \beta_2 C_{i,t} + U_i + Z_t + \varepsilon_{i,t}. \quad (6)$$

In the model,  $D_{i,t-\tau}$  is a dummy variable concerning the use of payment technology. If resident  $i$  is subject to the policy of using payment technology during period  $t - \tau$ , the variable takes the value of 1; otherwise, it is 0.  $m$  and  $n$  represent the number of periods before and after the policy implementation, respectively. Meanwhile,  $\beta_0$  is used to measure the policy effect of using payment technology, where  $\beta_{-m}$  to  $\beta_{-1}$  measure the policy effect of using payment technology in the previous 1– $m$  years;  $\beta_1$  to  $\beta_n$  represent the policy effect of using payment technology in the following 1– $n$  years.

Since the data in this paper are panel data for 2013, 2015, 2017 and 2019, the policy effects for seven years before and after policy implementation are considered to determine whether the sample has passed the parallel trend test. The X-axis 0 coordinate is unified as the starting point of the policy implementation in different regions, and the starting year of the policy in each region is different. Other values indicate the first  $n$  years and the last  $n$  years of the policy implementation, which are relative concepts. Figures 2 and 3 show that the estimated coefficients of total consumption and consumption structure before the use of payment technology hover around 0 and are not significant at the 90% level. However, after the use of payment technology, the estimated coefficients of total consumption and consumption structure are both significantly higher than 0 at the 90% significance level, indicating that the use of payment technology has led to significant differences in consumption between the experimental group and the control group. This satisfies the assumption of the parallel trend test, and the double fixed-effects time-varying difference-in-differences model can be used.

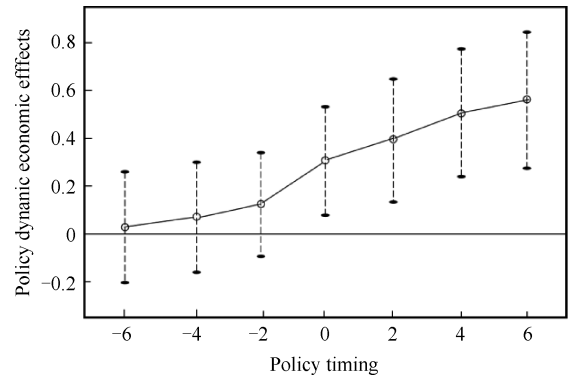


Fig. 2 Parallel trend tests with consumption level as dependent variable (90% confidence interval)

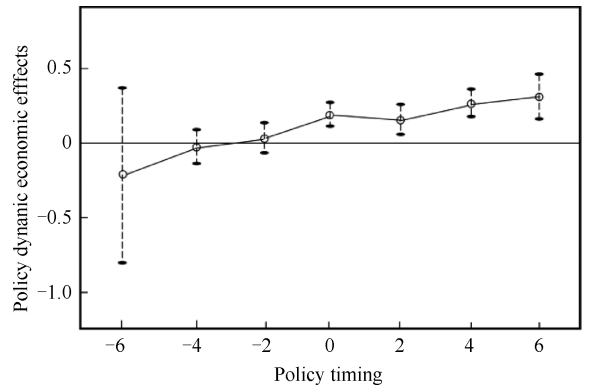


Fig. 3 Parallel trend tests with consumption structure as dependent variable (90% confidence interval)

### 3.2 Benchmark regression results

Subject to meeting the prerequisite of the parallel trend test, in order to overcome the endogeneity issue of sample data, the panel data from 2013, 2015, 2017 and 2019 are selected, fixing individuals and years. The time-varying difference-in-differences model is used to analyze the relationship between payment technology and the quantity and structure of residents' consumption. The specific results are shown in Table 2. Due to space constraints, the results tables are omitted. The same applies to the following sections.

Table 2 Baseline regression results

Variables	$y_1$		$y_2$	
$D$	0.213 9*** (11.78)	0.159 4*** (9.10)	0.112 2*** (10.00)	0.101 0*** (9.32)
Constant	YES	YES	YES	YES
Control variables	NO	YES	NO	YES
Individual fixed effects	YES	YES	YES	YES
Time fixed effects	YES	YES	YES	YES
$N$	24 927	24 898	24 897	24 868

Notes: The values in parentheses represent the coefficient values of each variable; \*\*\* indicates significance at the 1% level.

From the regression results, regardless of whether control variables are included, the coefficient of the *D* regression is significantly positive at the 1% level, indicating that the policy of using payment technology can significantly promote an increase in the quantity of residents' consumption and optimize consumption structure. Specifically, without including control variables, on average, each additional unit of payment technology use can significantly increase residents' total consumption by 0.21 units and promote an average optimization of consumption structure by 0.11 units. After including control variables, on average, each additional unit of payment technology use can significantly increase residents' total consumption by 0.16 units and promote an average optimization of consumption structure by 0.10 units. It can be considered that payment technology has helped to boost residents' consumption, achieving both expansion and upgrading in quality. This regression result validates the research Hypothesis 1 mentioned earlier.

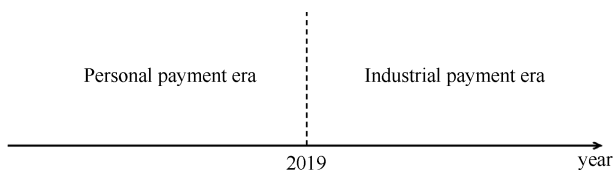


Fig. 4 Development of China's payment technology market

Since the issuance of payment business licenses in 2010, payment technology has significantly augmented the scale of payments in China through its technological applications, innovative functionalities, and user convenience, positioning the Chinese payment market as one of the foremost payment markets globally, currently situated in the era of personal payments. In 2019, the payment market transitioned into an epoch characterized by industrial payments. By 2023, in light of the wave of emerging technological revolutions, such as artificial intelligence, and in conjunction with the aforementioned regression results, we can anticipate that payment technology will facilitate an even swifter enhancement of the CEQI of residents' consumption.

### 3.3 Mechanism analysis

Building on the theoretical analysis and baseline regression results in the preceding sections, to further identify the mechanism by which payment technology facilitates the CEQI of residents' consumption, this study employs a moderated mediation analysis model to validate the three paths of influence: alleviating liquidity constraints, reducing transaction costs and weakening payment pain. This aims to determine whether they play a moderating role and to what extent.

#### 3.3.1 Test of the regulatory effect of alleviating liquidity constraints mechanism

We measure liquidity using two indicators: credit amount and SA index, analyzing effectiveness through statistical properties and economic significance. Table 3

shows that after introducing the interaction terms of credit amount and the use of payment technology, the coefficient of payment technology use remains significantly positive at the 1% level, and the coefficient of the interaction term remains significantly positive at the 10% level. This indicates that the liquidity constraint mitigation mechanism (measured by credit amount) plays a positive regulatory role in boosting residents' consumption expansion and upgrading through the promotion of payment technology. This regression result partially validates Hypothesis 1 proposed earlier.

Additionally, drawing on enterprise financing constraint indicators (SA index at the enterprise level), we construct an SA index at the micro-level of residents and use this index to measure the financing constraints faced by residents. Table 3 shows that after introducing the SA index and the interaction term of payment technology use, the coefficient of payment technology use remains significantly positive at the 1% level, while the coefficient of the interaction term is significantly negative in the regression on total consumption and not significant in the regression on consumption structure. This indicates that the liquidity constraint mitigation mechanism (measured by the SA index) plays a positive regulatory role in promoting residents' consumption expansion through payment technology but cannot play a positive regulatory role in promoting residents' consumption upgrading through payment technology. The SA index is always negative, and the larger the SA index, the closer to 0, indicating a greater financing constraint and smaller liquidity. This regression result partially validates Hypothesis 2 proposed earlier. The reason may be that consumers facing greater financing constraints are more likely to face basic survival issues, making it more difficult for them to engage in higher-level enjoyment-oriented consumption.

#### 3.3.2 Test of the regulatory effect of reducing transaction costs mechanism

For the cost reduction indicator, we measure it using the level of informatization. Table 3 shows that after introducing the level of informatization and the interaction term of payment technology use, the coefficient of payment technology use and the coefficient of the interaction term are both significantly positive at the 1% level. This indicates that the transaction cost reduction mechanism plays a positive regulatory role in boosting residents' consumption expansion and upgrading through payment technology. This regression result validates Hypothesis 3 proposed earlier.

#### 3.3.3 Test of the regulatory effect of weakening payment pain mechanism

Table 3 shows that after introducing the consumer price index and the interaction term of payment technology use, the coefficient of payment technology use and the coefficient of the interaction term are both significantly positive at the 1% and 10% levels, respectively. This indicates that the payment discomfort

mitigation mechanism plays a positive regulatory role in boosting residents' consumption expansion and upgrading

through payment technology. This regression result validates Hypothesis 4 proposed earlier.

**Table 3** Summary of test results of regulatory effects

Variables	$y_1$	$y_2$	$y_1$	$y_2$	$y_1$	$y_2$	$y_1$	$y_2$
$D$	0.136 9*** (4.38)	0.063 1*** (3.14)	0.165 0*** (9.20)	0.100 2*** (9.24)	0.138 2*** (7.61)	0.089 5*** (8.13)	0.166 8*** (9.13)	0.096 9*** (8.32)
$L$	-0.000 3 (-1.15)	-0.001 2*** (-3.86)						
$D_c L_c$	0.000 2* (1.74)	0.000 9*** (9.63)						
$X$			-0.022 7 (-0.42)	-0.095 4 (-0.64)				
$D_c X_c$			-0.079 7*** (-4.16)	0.014 0 (0.90)				
$V$					-0.000 1 (-0.29)	-0.000 9*** (-3.17)		
$D_c V_c$					0.002 4*** (7.21)	0.001 2*** (6.10)		
$D_c P_c$							-0.046 0*** (-2.72)	0.025 7* (1.75)
Constant	YES	YES	YES	YES	YES	YES	YES	YES
Control variables	YES	YES	YES	YES	YES	YES	YES	YES
Individual fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Time fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
$N$	12 366	12 316	24 898	24 868	24 870	24 840	24 898	24 868

Notes:  $L_c$ ,  $X_c$ ,  $V_c$  and  $P_c$  represent the decentralized  $L$ ,  $X$ ,  $V$  and  $P$ , respectively; \* indicates significance at the 10% level.

**3.4 Analysis of the interaction relationships**

To further explore how moderator variables play a moderating role in CEQI of residents' consumption through payment technology, the relationship between moderator variables is further examined. Due to the

partial verification of Hypothesis 2 when the SA index is used as an indicator of liquidity constraint relief, only the credit limit is used as a test indicator to explore the relationship between moderator variables. The results are shown in Table 4.

**Table 4** Moderating variable correlation table

Variables	$L$	$L$	$V$
$L$	0.833 9 (1.29)		
$P$		1 404.611 4*** (0.21)	5.800 0*** (-3.01)
Constant	YES	YES	YES
Control variables	YES	YES	YES
Individual fixed effects	YES	YES	YES
Time fixed effects	YES	YES	YES
$N$	250	250	500

Table 4 shows that the liquidity constraint relief effect does not significantly affect the reduction in transaction costs effect, while the weakening of payment pain effect can significantly influence the liquidity constraint relief effect and reduction in transaction costs effect at the 1% significance level. Therefore, it can be inferred that the processes of liquidity constraint relief effect and reduction in transaction costs effect are jointly regulated in promoting the expansion and enhancement of residents' consumption through payment technology. Additionally, the weakening of payment pain effect is respectively interconnected with the liquidity constraint relief effect and reduction in transaction costs effect in regulating the process of promoting the CEQI of residents' consumption through payment technology (Fig. 5).

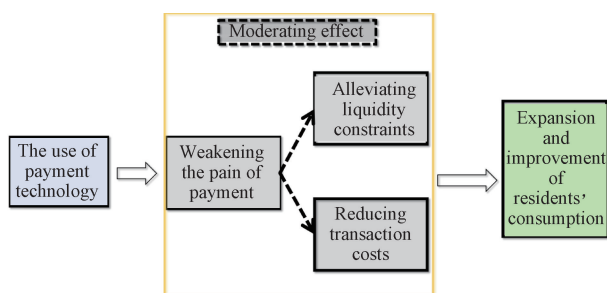


Fig. 5 Correlation plot of moderating effect variables

## 4 Robustness Discussion and Heterogeneity Analysis

In this section, based on the analysis of the

benchmark model and mechanisms, a series of robustness tests are conducted, including randomized placebo tests, sample data truncation processing and exclusion of contemporaneous policy effects.

### 4.1 Robustness discussion

#### 4.1.1 Randomized placebo test

In economics, the placebo test is similar to that in medicine. It examines whether the trend changes in the treatment group and the control group after the policy intervention point are influenced by other policies or random factors. This is done to assess the robustness of the basic test using the time-varying difference-in-differences model. This paper further validates whether the use of payment technology can promote the CEQI of residents' consumption by comparing the treatment group and the control group. Drawing on relevant literature, this study adopts the method of randomly generating treatment groups. The codes representing households are extracted and converted into continuous variables. After randomly shuffling the data, 30 samples were drawn each time as pseudo-policy experimental groups, matched with the original data, and then interacted with the pseudo-policy occurrence time to generate pseudo-policy dummy variables. This process is repeated 500 times in Stata. The estimated coefficient distribution and corresponding *p*-values of the pseudo-policy dummy variables in the randomized regression of total consumption and consumption structure over 500 experiments are obtained (Fig. 6).

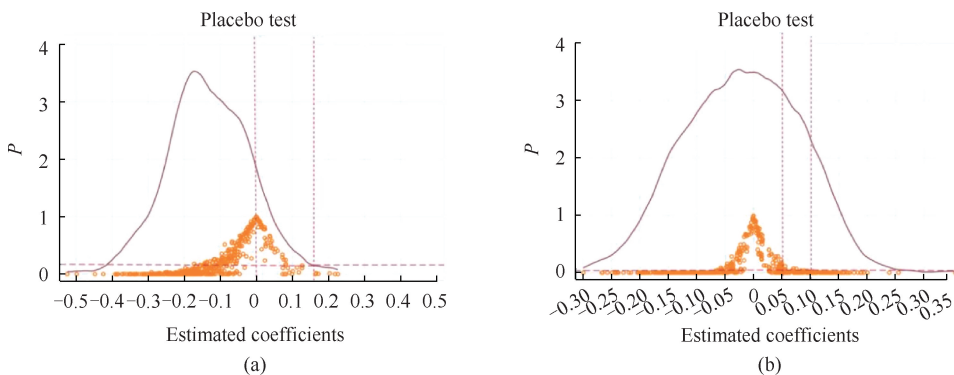


Fig. 6 Placebo testing for estimated coefficients: (a) total consumption; (b) consumption structure

In Fig. 6, the *X*-axis represents the estimated coefficient magnitude of the pseudo-policy dummy variable; the *Y*-axis represents the kernel density and *p*-value magnitude; the curve represents the kernel density distribution of the estimated coefficients of the pseudo-policy dummy variable; the dots represent the corresponding *p*-values of the estimated coefficients. Figure 6 shows that the estimated coefficients of the pseudo-policy dummy variables for total consumption and consumption structure mainly concentrate at  $-0.2-0$  and

$-0.1-0.1$ , respectively. Therefore, the baseline regression results of 0.1594 and 0.1010 can be regarded as marginal outliers for the two indicators, respectively. Additionally, the majority of the *p*-values for the estimated coefficients of the pseudo-policy dummy variables are greater than 0.01, indicating that the baseline regression results are not accidental and that other random factors have not significantly interfered with the promotion of residents' total consumption growth and the optimization of consumption structure by payment technology.

#### 4.1.2 Sample data

To prevent the influence of outliers on the regression results, a 1% data truncation on the dependent variables is conducted from both the top and the bottom. The values of the dependent variables in the sample greater than the 99th percentile are replaced with the observation value of the 99th percentile, while the values of the dependent variables in the sample less than the 1st percentile are

replaced with the observation value of the 1st percentile. Through the above operation, the dependent variables ( $y_{1_w}$  and  $y_{2_w}$ ) after sample data truncation are obtained, and further robustness tests are conducted by comparing the descriptive statistical results of the dependent variables before and after truncation (Table 5) and the baseline regression results before and after truncation (Table 6).

**Table 5** Descriptive statistics of dependent variables before and after truncation

Variables	N	Mean	Standard deviation	Minimum	Maximum
$y_1$	24 927	10.570 5	0.963 3	0	18.948 6
$y_{1_w}$	24 927	10.574 6	0.914 8	8.091 3	12.811 1
$y_2$	24 897	-0.843 9	0.635 4	-9.655 1	0
$y_{2_w}$	24 897	-0.836 9	0.598 7	-3.044 5	-0.039 4

**Table 6** Baseline regression results before and after truncation

Variables	$y_1$		$y_{1_w}$		$y_2$		$y_{2_w}$	
<i>D</i>	0.213 9*** (11.78)	0.159 4*** (9.10)	0.211 9*** (12.33)	0.160 3*** (9.96)	0.112 2*** (10.00)	0.101 0*** (9.32)	0.110 0*** (10.24)	0.099 5*** (9.52)
Constant	NO	YES	NO	YES	NO	YES	NO	YES
Control variables	YES	YES	YES	YES	YES	YES	YES	YES
Individual fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
Time fixed effects	YES	YES	YES	YES	YES	YES	YES	YES
<i>N</i>	24 927	24 898	24 927	24 898	24 897	24 868	24 897	24 868

Tables 5 and 6 show that the range of total consumption and consumption structure without truncation of sample data is significantly larger than that after truncation, indicating the possible presence of outliers in the initial data. Truncating the sample data does not change the significance level of the core explanatory variables. After truncation, the values of the regression coefficients are not significantly different from those before truncation and almost all show a slight decrease, reflecting a weakening impact of payment technology on CEQI of residents' consumption after data truncation. The baseline regression results are more robust after data truncation.

#### 4.1.3 Exclude concurrent policy effects

Apart from payment technology, other concurrent policies may also affect the CEQI of residents' consumption. To test whether the policy effect of payment technology on the CEQI of residents' consumption is a net effect and whether there are other policies that can affect the CEQI of residents' consumption, this paper selects the China's cross-border e-commerce comprehensive pilot zone (CCECPZ) as the concurrent policy that needs to be excluded. In March 2015, the State Council approved Hangzhou as the first China's cross-border e-commerce comprehensive pilot zone. By the end of 2022, China had established a total

of seven batches of 165 Comprehensive Pilot Zones for Cross-border E-commerce in China, involving 31 provinces.

The establishment of the China's cross-border e-commerce comprehensive pilot zone has various impacts on residents' consumption. On the one hand, the pilot zone allows direct procurement of goods from abroad, avoiding markups in intermediate links, reducing residents' consumption costs, and promoting the expansion of residents' consumption. On the other hand, the pilot zone introduces more international brands and high-quality products with new styles and technologies, thus improving the quality of residents' consumption. Therefore, this paper selects the policy indicators of three batches of the China's cross-border e-commerce comprehensive pilot zone from 2013 to 2019. The establishment date of the fourth batch was December 15, 2019, with a shorter impact time on consumption in that year, hence not considered. The policy of the China's cross-border e-commerce comprehensive pilot zone is introduced into the baseline regression, with a dummy variable *R* set. If a city is designated as the China's cross-border e-commerce comprehensive pilot zone starting from a certain year, then  $R=1$  for that year and subsequent years; otherwise,  $R=0$ . The regression results are shown in Table 7.

**Table 7** Regression results table excluding contemporaneous policy influence

Variables	$y_1$	$y_2$
<i>D</i>	0.2057*** (15.69)	0.1493*** (10.45)
<i>R</i>	-0.0475 (-0.14)	0.0346 (0.23)
Constant	YES	YES
Control variables	YES	YES
Individual fixed effects	YES	YES
Time fixed effects	YES	YES
<i>N</i>	500	500

Table 7 shows that after excluding the policy effect of the China's cross-border e-commerce comprehensive pilot zone, there was no change in the significance of the core explanatory variables. Additionally, the regression coefficient of the policy variable China's cross-border e-commerce comprehensive pilot zone is not significant. This could be because the policy of the China's cross-border e-commerce comprehensive pilot zone did not have a significant impact on residents' consumption during the same period, or it may be due to a time lag in the implementation of this policy. In any case, it can be considered that in the analysis of the role of payment technology on residents' consumption, there was no interference from the simultaneous policy of the China's cross-border e-commerce comprehensive pilot zone, further demonstrating the robustness of the regression in this paper.

## 4.2 Heterogeneity analysis

### 4.2.1 Urban-rural household registration heterogeneity

To better illustrate the impact of payment technology on CEQI of residents' consumption, this study conducts

a heterogeneous analysis of two indicators: total consumption and consumption structure, based on the factors of urban and rural household registration and financial literacy. Tables 8 and 9 show that within the framework of relative income theory, urban-rural income inequality stimulates urban residents' comparison psychology and rural residents' social status-seeking psychology. Specifically, urban residents, situated at the higher income end, engage in conspicuous consumption to increase consumption due to their comparison psychology and ample spending power. Conversely, rural residents, positioned at the lower income end, tend to save wealth to enhance social status, resulting in the significant impact of payment technology on urban consumers being higher than that on rural consumers<sup>[23-26]</sup>. However, under the effect of residents' rational expectations correction, the pull effect of payment technology on optimizing consumption structure for rural residents may be more pronounced than for urban residents due to the unreasonable consumption structure of rural residents themselves.

### 4.2.2 Financial literacy heterogeneity

Tables 8 and 9 show that payment technology has a higher effect on CEQI of residents' consumption for high financial literacy consumers than for low financial literacy consumers. This is because the former often possess abundant knowledge of financial markets, complex calculation abilities and rational investment thinking, which enables them more adept at using payment technology (such as low or interest-free credit) to engage in cost-saving forward consumption. Simultaneously, they can optimize their consumption structure, thereby improving their living standards<sup>[27-29]</sup>.

The overall consumption heterogeneity results and consumption structure heterogeneity regression results are shown in Tables 8 and 9 respectively.

**Table 8** Overall consumption heterogeneity regression results

Variables	Rural	Urban	Low financial literacy	High financial literacy
<i>D</i>	0.1214*** (6.25)	0.2391*** (8.91)	0.1363*** (7.29)	0.3399** (12.96)
Individual fixed effects	YES	YES	YES	YES
Time fixed effects	YES	YES	YES	YES
<i>N</i>	13133	11722	359	186

Note: \*\* indicates significance at the 5% level.

**Table 9** Consumption structure heterogeneity regression results

Variables	Rural	Urban	Low Financial Literacy	High Financial Literacy
<i>D</i>	0.1029*** (7.07)	0.1021*** (6.20)	0.1101*** (5.88)	0.2882** (35.62)
Individual fixed effects	YES	YES	YES	YES
Time fixed effects	YES	YES	YES	YES
<i>N</i>	13126	11699	359	186

## 5 Conclusions

This study uses panel data from CHFS2013–2019, supplemented by data from the China Statistical Yearbook published by the National Bureau of Statistics and data from Digital Inclusive Finance published by Peking University, to study and analyze the policy effects of payment technology in promoting the CEQI of resident's consumption. The conclusions are as follows.

Firstly, the baseline regression results show that whether or not control variables are included, payment technology is significantly positively correlated with the quantity and structure of residents' consumption. Therefore, we can confirm the basic assumption of this paper, that payment technology promotes residents' consumption, achieving CEQI.

Secondly, this paper uses the moderation effect test model to verify the implementation path of payment technology in promoting the CEQI of residents' consumption. The results of the moderation effect test show that alleviating liquidity constraints, reducing transaction costs and weakening payment pain all have positive moderating effects in the process of payment technology promoting the CEQI of resident's consumption. Therefore, we can conclude that payment technology promotes the CEQI of residents' consumption by alleviating liquidity constraints, reducing transaction costs and weakening payment pain.

Finally, based on the baseline regression, this study further explores the relationship between payment technology and residents' consumption through heterogeneity analysis. The results show that differences in household registration (urban or rural) and financial literacy both have heterogeneous effects on the process of payment technology impacting the ECQI of residents' consumption. Specifically, compared to rural consumers, payment technology has a greater effect on consumption ECQI for urban consumers. Compared to consumers with low financial literacy, payment technology has a better effect on consumption ECQI for those with high financial literacy.

## 6 Suggestions

### 6.1 Demand side

1) Promote payment technology adoption and financial literacy

To encourage greater consumer use of payment technology, it is essential to enhance financial literacy. This involves educating consumers on the fundamentals of payment technologies and financial management, including basic financial knowledge and relevant policies. Additionally, efforts should focus on raising awareness of risk prevention and anti-fraud practices, fostering healthy financial values, and guiding responsible borrowing and consumption to avoid blind following and wasteful

spending.

2) Boost income and consumer willingness

Income is a critical determinant of consumption. To stimulate consumption, it is vital to adhere to an innovation-driven development strategy, advance the transformation of traditional industries, and foster high-value-added sectors, thereby ensuring the sustainable growth of the Chinese economy. Strengthening social security measures is also necessary to bolster consumer confidence.

3) Reduce regional disparities and promote social equity

Tailored approaches are needed to achieve coordinated regional development. Efforts should focus on enabling more prosperous areas to support less developed ones, and urban centers to uplift rural regions. By narrowing the economic gaps between urban and rural areas, and among different regions and city tiers, social equity can be promoted, thereby increasing consumer confidence and overall consumption across the country.

### 6.2 Supply side

1) Optimize product supply and quality

High-quality products are essential to harness the full potential of payment technology in driving consumption. This requires strengthening the industrial chain, transportation, and industrial infrastructure to ensure adequate product supply. Simplifying market entry for payment technology providers, reducing entry barriers, and encouraging competition will foster innovation. Continuous research and development should focus on enhancing product diversity, appearance, and quality to support the transformation of consumption patterns.

2) Improving top-level design and public services

Enhancing the basic market economy systems, including property rights, market access, fair competition, and social credit, is crucial. Efforts should be made to create a market-oriented, legal, and internationalized business environment. The government should build a new type of government-business relationship, reduce business costs, and promote a standardized, competitive, and efficient transaction and consumption environment. Strengthening oversight of the payment technology market will protect consumer rights and ensure payment service safety. Additionally, increasing investment in digital infrastructure, such as 5G networks, the Internet of Things, and big data platforms, will provide a robust foundation for the development of new productive forces.

### 6.3 Technological side

1) Enhance credit supervision and improve services

Improving user data confidentiality and personnel management is critical, as data breaches undermine trust in payment technology. A balanced approach is needed to manage lending platform data rights and consumer data, considering both security and efficiency. Strengthening user information management will reduce default risks. Establishing a robust feedback system to incorporate

consumer suggestions and continuously improve services will enhance user satisfaction.

2) Advance research and ease of use

Standardization and interoperability of payment systems should be prioritized to enhance service convenience and accessibility. Efforts should focus on developing payment products tailored to middle-aged and elderly users, making technology more accessible to these groups. Increased investment in payment technology research is necessary to drive innovation, integrate payment technology with emerging technologies like big data and AI, and expand its application in areas like digital currency.

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## 支付科技助推居民消费扩容提质的赋能机制与实证分析

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**摘要:** 基于流动性约束、消费者均衡及双通道心理账户等理论剖析了支付科技助推居民消费扩容提质的作用机理。运用多期双重差分模型识别支付科技对居民消费的影响, 采用调节效应分析方法识别其作用机制。研究发现, 支付科技是通过流动约束缓解、交易成本降低及支付痛感削弱三条路径助推消费扩容提质的。对三者的串并联机制进行了探讨。支付科技对居民消费扩容提质的效应会因城乡户籍和金融素养的差异, 呈现出明显的异质性。基于实证研究结果和中国国情, 分别从需求端、供给端和技术端提出针对性的政策建议。

**关键词:** 支付科技; 扩容提质; 居民消费; 新质生产力; 多期双重差分模型; 调节效应